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DUST RETARDATION STUDIES OF CARBON DIOXIDE SORBENTS

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MSA Research Corporation

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FOREWORD

This research was initiated by the Life Support Division, Biomedical Laboratory, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. The research was conducted by MSA Research Corporation, Evans City, Pennsylvania, under Contract No. F33015-67-C-1516, and in support of Project 6373, "Equipment for Life Support in Aerospace," and Task 637302, "Respiratory Support Equipment." The research program covered the period from April 1967 to February 1968. Mr. C. M. Meyer, Biotechnology Branch, Life Support Division, was the contract monitor for the Aerospace Medical Research Laboratories. This research was supported in whole by the Aerospace Medical Research Laboratories Commander's Fund.

This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
Biomedical Laboratory
Aerospace Medical Research Laboratories

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ABSTRACT

Surfaces of CO₂ sorbent granules were treated with various liquid preparations to diminish dusting tendency and to improve CO₂ dynamic capacity. Emphasis was placed on a screening program whereby granules of LiOH were impregnated with solutions of surfactants, organic polymers, and lithium halide salts. Relative effectiveness of treatment was evaluated using a CO₂ dynamic capacity test and a dust test. Studies show that latex emulsions significantly diminish dusting tendency of LiOH granules with only negligible loss in CO₂ sorption capacity. LiCl-treated LiOH results in significantly improved CO₂ capacity at low humidity, but such treatment is generally less effective as a deduster than the latex preparation. Excess loadings of surfactants were required to diminish dusting to acceptable limits.

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SECTION I INTRODUCTION

Various solid inorganic compounds have been used in life support systems as chemical sorbents for carbon dioxide. One of the principal difficulties associated with use of such chemicals is the formation of irritating dust during mechanical agitation or when the sorbent bed is exposed to the process air stream. Some of these dusts are especially noxious and necessitate use of various filtration schemes.

Previous experiments at MSAR suggested surface treatment techniques that could retard dusting of life support chemical sorbents without appreciable loss of carbon dioxide sorption capacity. The treatment methods involved surface reaction of the solid caustic chemical with acid to form deliquescent salts that appeared to inhibit surface dusting.

The objectives of this effort were twofold: to diminish the dusting tendency of CO_2 sorbent granules and to improve the dynamic CO_2 capacity of the sorbent. Of the two objectives, the former was of prime concern.

Program studies primarily used lithium hydroxide as the test sorbent substrate, as this material is an excellent CO_2 sorbent on both a weight and volume basis. In use, however, lithium hydroxide readily yields a highly irritable dust.

The experimental program consisted largely of an extensive screening program whereby sorbent granules were impregnated with solutions of surfactants, organic polymers, and lithium halide salts. The relative effectiveness of each type treatment was evaluated using a dynamic CO_2 capacity test and a dust test. The CO_2 capacity was measured dynamically by flowing a 1% CO_2 air stream at 27 C (80 F), 80% RH through test beds at a superficial velocity of 0.089 m/sec (17.4 ft/min) until the effluent concentration reached 0.5% CO_2 . Tendency to dust was determined by tumbling the treated granules followed by washing the fines through a 60-mesh Tyler screen with dry benzene. A final evaluation method consisted of eluting dust from prepared beds by an air sweep at several bed velocities.

SECTION II EVALUATION METHODS

Evaluation test methods were required that could rapidly and reproducibly measure the influence of the treatment methods on the ability of the sorbent to remove CO₂ and the tendency of the granules to form dust or fines. The methods selected are discussed below in detail.

DYNAMIC CO₂ CAPACITY TEST

The dynamic CO₂ capacity of a material can be described as the total amount of CO₂ absorbed up to a point where the CO₂ content in the effluent stream reaches some arbitrary concentration. The theoretical capacities of sorbent material are well known, but bed utilization efficiencies can vary widely with flow conditions and geometry. To minimize the scatter of data resulting from changing conditions from day to day, a control or untreated material was run during every test. In brief, the test consisted of flowing a 1% CO₂ air stream through a prepared bed until the effluent concentration reached 0.5%. Total absorption of CO₂ at this point was a measure of the CO₂ capacity. Tests were run at room temperature with no attempt to control bed temperatures. The test conditions throughout most of the screening program are listed below:

CO₂ CAPACITY TEST CONDITIONS

Bed Dimensions	15 g charge LiOH, 3.0 cm ID x 3.17 cm high
CO ₂ Input	1% in clean air
CO ₂ Effluent	0.5 % (breakpoint)
Relative Humidity	78-80%
Temperature	25-27 C (77-81 F)
Flow Rate	4.0 liters/min or 532 cc/min/ cm ² bed
Superficial Velocity	0.089 m/sec (17.4 ft/min)

The apparatus used to evaluate CO₂ dynamic capacity is pictured in Figure 1. The device is capable of monitoring the effluent from 6 beds while providing a means of checking the CO₂ influent concentration.

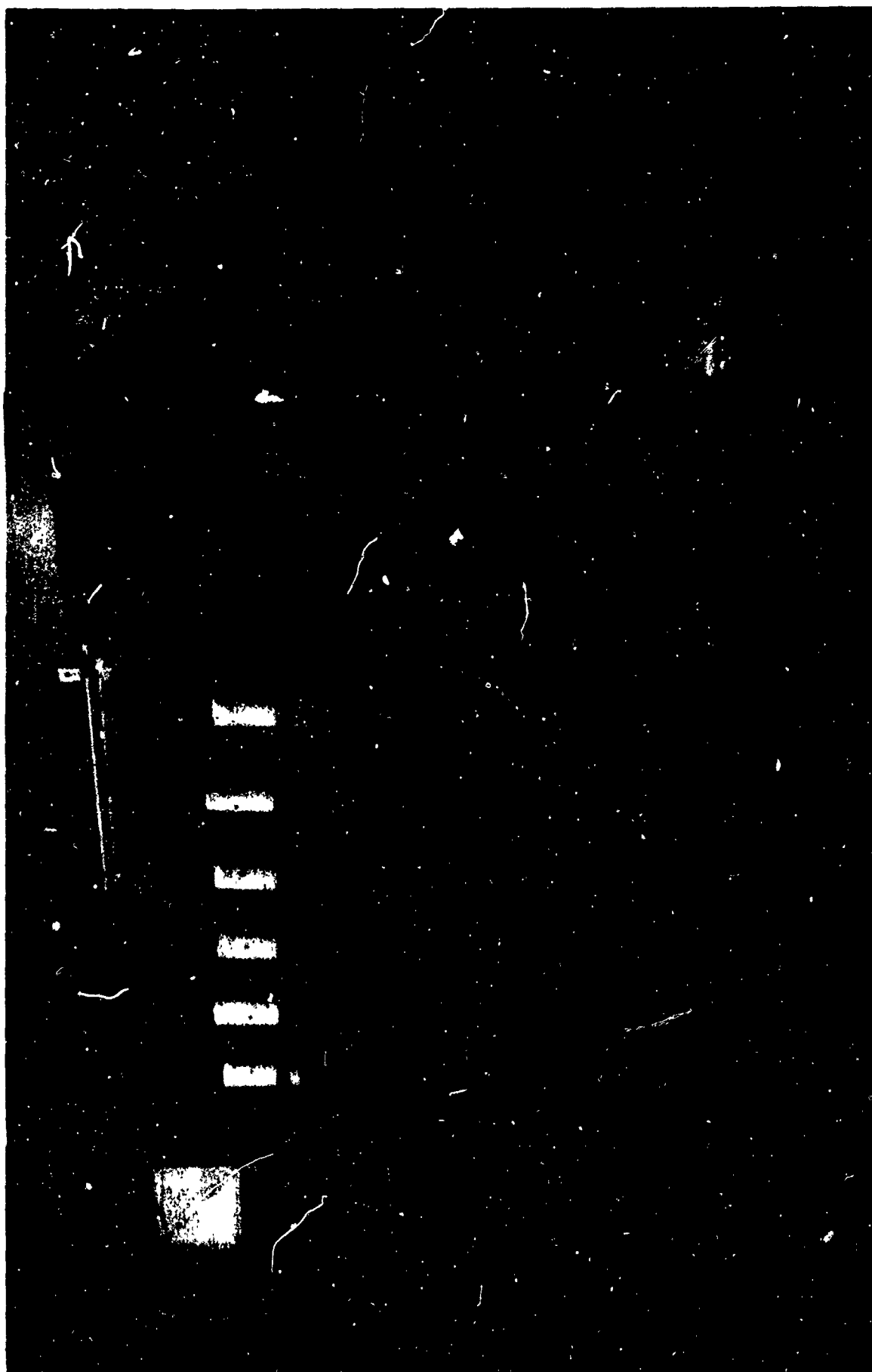


Figure 1. Dynamic CO₂ Sorption Test Apparatus

The concentration used almost exclusively was 1% CO_2 in clean air and was obtained by proper proportioning of air and CO_2 streams. Proper humidity levels were obtained by flowing the air streams over and around warm water contained in a 1000 cc flask in a heating mantle. Humidity was measured by a wet-dry bulb combination. In operation about 30 liters/min of test gas was generated, with about 24 liters actually employed in the test (6 beds, 4 liters/min each) and excess gas vented. To drive the gas through each of the beds, it was necessary to maintain 2 psig on the manifold. Consequently, all data collected is at a slight positive pressure.

Bed containers were of glass and were adapted from glass frits (Fisher Scientific, Cat. No. 11-136, 30 mm course) that were treated with dilute HF to minimize resistance to flow. Overall height of each bed container was 10", giving a 6" height above the frit (45-50 g LiOH capacity). Each bed in place was equipped with a U-tube to measure resistance to flow across the bed.

Flow of gas through each bed was monitored and controlled by a flow meter and valve downstream from the bed. Flow passing through each bed and flow meter was diverted either to exhaust or to the concentration monitor by means of a three way stopcock.

CO_2 concentration in all bed gas streams (manifold, bed effluents) were monitored by a MSA LIRA, Model 300. Two scales are available - 0-5% and 0-2% full range. The instrument was calibrated using prepared CO_2 test gas.

DUST TEST

Some difficulty was encountered in devising a dust test suitable for the varied treatment methods. Attempts to measure dust generated by vibrating a bed of sorbent generally did not impart the same degree of motion to all particles. This was especially true of sorbent containing high surface loadings which barely moved under the same amount of energy input that caused untreated granules to move freely. In the case of high surfactant add-on, some additives were removed by the walls of the container that, in turn, trapped additional fines. The method eventually used consisted of the following:

1. A quantity of sorbent slightly in excess of 10 g was shaken lightly on a No. 14 Tyler screen. Dust loosely adhering to the granule and screen was dislodged by a stream of dry nitrogen.

2. Ten grams of each treated sorbent was placed in a 60 cc screw cap jar. Normally, 5 treated and 1 untreated sample (control) were run at one time. The device used for tumbling was a converted ball mill (Paul O. Abbe, N.S.) The adapted unit is shown in figure 2.
3. In operation, each jar was rotated at 56-58 rpm for 10 minutes. At the end of 10 minutes, each jar was allowed to stand to permit the generated dust to settle.
4. The contents of each jar and cap was wetted down with dry benzene and then transferred to a 60-mesh Tyler screen resting on a 1000 ml beaker. The granules were washed thoroughly by a fine stream of benzene from a plastic squeeze bottle. Exactly 180 cc of dry benzene per 10 g sample was required.
5. After the washings had drained into the beaker, the glass jar was washed with water and the washings added to the benzene and dust previously collected in the beaker. About 150 cc of distilled water was added to the beaker and contents mixed thoroughly with a magnetic stirrer.
6. Contents of the beaker (dissolved LiOH and benzene) were added to a 500 ml separatory funnel and phases allowed to separate.
7. The water containing the dissolved sorbent was determined by acid titration (0.1N HCl) or flame photometry.

A final evaluation test, used only on selected candidate systems, consisted of eluting dust from prepared beds at several superficial gas velocities. The number of dust particles in the 0.5 to 0.64 μ range was counted by a Royco Model 200A Particle Counter. Experience with this particular test method was limited.

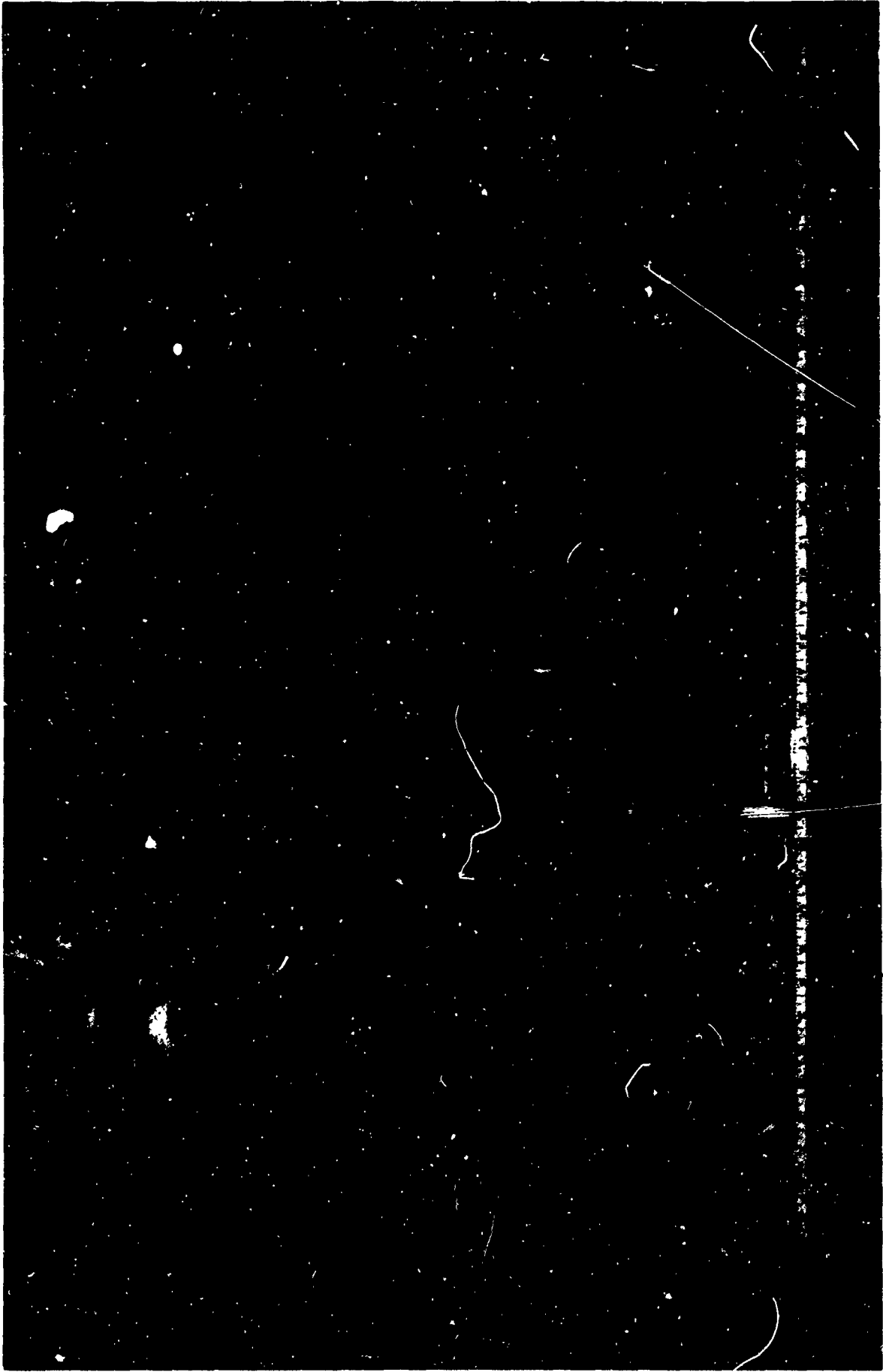


Figure 2. Dust Shaker Test Unit

SECTION III SORBENT TREATMENT STUDIES

SURFACTANTS

Interest in the use of surfactants was generated chiefly by the use of surfactants to minimize the spread of dust during handling of fine chemicals. At first only the non-ionic surfactants were considered, but eventually this listing was expanded to include the anionic and cationic series.

The sorbent substrate selected for study was anhydrous LiOH supplied by Lithium Corporation of America. The method of treating the sorbent with the surfactant consisted of dipping the sorbent granules (contained in flat trays) into baths of the prepared surfactant solution. It was not practical to determine the amount of surfactant actually picked up following this operation.

For the most part, the surfactants selected for study were recommended by the manufacturer as having a reasonable stability in the presence of alkali. In some cases, materials were tested merely because they represented classes of compounds not previously examined.

The data obtained from screening these materials is shown in tables I and II. Bed charge in each case was 15 g. The CO₂ dynamic capacity (27 C [78 F], 80% RH) is presented as a percentage of the untreated material that was run as a control on the same day. The quantity of CO₂ removed was determined by plotting effluent concentrations with time and determining areas under the curve with a planimeter. The dust index refers to untreated material as unity. Thus a dust index of 0.6 indicates that treatment has produced a product yielding only 60% as much dust as untreated material. The specific method of treatment consisted of preparing a bath solution of the surfactant dissolved in a suitable non-aqueous solvent. Granules of LiOH were spread on flat trays and immersed in the treatment bath until completely covered. Dip time was about 15 to 30 seconds, or until all gas (air) evolution ceased. The treated material was dried at 80 C (176 F) for 3 hours.

As can be observed from the table, some dedusting can be achieved provided sufficient surfactant is available. This is especially evident in the L-45 silicone series, where dusting tendency diminished with increasing silicone loading. However, the dedusting is achieved at a significant loss of CO₂ activity.

TABLE I - DUSTING AND CO₂ SORPTION OF
SURFACTANT TREATED LIOH

<u>Trade Name</u>	<u>Surfactant Type</u>	<u>Vehicle</u>	<u>Bath & Conc.</u>	<u>Relative CO₂ Performance Treated/Untreated</u>	<u>Dust Index</u>
L-45 Silicone	dimethylpolysiloxane 10,000 centistokes	Pet Ether	0.5	97	1.0
			1.0	88	0.9
			2.0	66	0.7
			4.0	49	0.5
			6.0	40	0.6
L-45 Silicone	dimethylpolysiloxane 50 centistokes	Pet Ether	0.2	100	0.8
			0.4	96	0.7
			0.7	86	0.6
			1.0	63	0.5
SC-3900 Organosilicon	Gamma-aminopropyl triethoxy silane	Hexane	0.1	100	1.2
			0.3	100	1.1
			0.6	95	.9
SC-4098 Organosilicon	Silicone solution	Hexane	0.1	95	1.1
			0.3	87	1.3
			0.6	95	1.3
SS-4029	Silicone solution	Hexane	0.1	100	1.2
			0.3	87	1.1
			0.6	87	1.3
Liponic y500-70	ethoxylated Oleyl Alcohol	Tetrahydrofuran	0.75	95	1.1
			1.1	92	0.9
			1.5	95	0.9
			2.2	91	0.8
Tergitol Min foam	Nonionic linear alcohol ethoxylate	MeOH	0.8	95	0.6
Cerfac 1300	Nonionic Polyether alcohol	MeOH	0.8	109	1.1
Sulfonic A-3	Nonionic polyether	MeOH	0.8	95	1.1
Antarox al-344	Nonionic aliphatic polyether	MeOH	0.8	100	1.2
Lonic #212	Nonionic polyether	MeOH	0.8	95	0.9
Tween 40	Nonionic polyoxy- ethylene sorbitol monopalmitate	MeOH	0.8	101	0.9
Tween 80	Nonionic polysorbate	MeOH	0.8	101	0.8
Renex 20	Nonionic poly- ethylene esterol fatty and resin acids	MeOH	0.8	103	0.9

TABLE II - DUSTING AND CO₂ SORPTION OF SURFACTANT TREATED LIOH

Trade Name	Surfactant Type	Vehicle	Dust Conc.	Relative CO ₂ Performance Treated/Untreated	Dust Index
Ultravon JC	Anionic ethylene oxide condensate	MeOH	0.8	100	0.8
PS-222	Anionic, Phosphate Ester	MeOH	0.8 1.6 3.0	100 86 78	0.43 -- --
Triton Q5-30	Anionic, Phosphate Ester	MeOH	0.8	95	
Aerosol RA80	Anionic, Sodium dihexyl sulfosuccinate	MeOH	0.3	--	1.1
Eneol 05-10	Anionic, sodium 2-ethylhexyl sulfate	MeOH	0.8	95	1.2
Duponol 42C	Anionic, Sodium Lauryl Sulfate	MeOH	1.0	92	2.0
Duponol 4A Paste	Anionic, Sodium Lauryl Sulfate	MeOH	1.2	100	2.0
Cheradene 300	Amphoteric Amine Salt	MeOH	0.8 1.0 2.0	109 108 110	1.1 -- --
FC-98	Anionic, Fluorochemical	MeOH	0.8	109	1.3
FC-128	Anionic, Fluorochemical	MeOH	0.8	108	1.1
Ultravon JC	Anionic Sulfonated benzimidazol	MeOH	0.8	109	0.4
Sapamine CC	Cationic, amino derivatives	MeOH	0.7	92	
3-amin-4L	Cationic, amino derivatives	MeOH (50%)	0.8	92	

Surfactants were expected to be much more effective in lesser amounts. The mechanical or physical role expected of the surfactant was that it would serve as a lubricant in reducing particle attrition. In addition, interaction of similarly coated surfaces should aid a larger granule in sequestering or retaining tiny fragments.

A serious disadvantage of the use of surfactants in the amount indicated is the likely possibility that air passing through a treated sorbent bed would sweep surfactant vapor downstream. The actual toxicological threat posed by vapors of surfactants is uncertain. In almost all instances, users of surfactants are cautioned by manufacturers against breathing of the vapors. Under conditions that CO_2 sorbents would likely be used, toxic vapors could readily be swept from the beds with resulting physiological affects. Recycling the air stream without additional stream clean up would most likely lead to a concentration of contaminated vapors approaching saturation levels. In a limited study using free amines (diethylenetriamine) and Arnflo 610 (C_{16} amine), pungent odors evolved from the treated material.

Although the possibility existed that a nonvolatile nontoxic material could be found, the data indicated that surfactants (and monomeric systems including free amines) do not impart sufficient binding strength to the sorbent granule to minimize fragmentation and subsequent dispersal of fines.

At this point interest diminished in the use of organic monomers, such as surfactants and free amines. Although this particular study did not yield a likely candidate system, the study crystallized the general type of solution desired. Envisioned was a film coat that would completely encapsulate the sorbent granule in a protective yet permeable sheathing. In addition, it should be nontoxic, nonvolatile, elastic, and adhesive. Ideally, the film coat should possess a certain reactivity toward CO_2 , in which case the added weight could be employed more effectively. These considerations led to the use of polymeric systems that could be formed in place about the sorbent granule. This study is described next.

ORGANIC POLYMERS

Water-soluble polymers are used extensively. Consequently, a large number of preparations exist. Polymers of this class are presently used in textiles, cosmetics, food-stuffs, and also significantly in pharmaceuticals as tablet binders. The listing of available materials is considerably greater than indicated by the number of materials actually screened.

Common to most of the preparations examined is that the material was available in polymer rather than monomer form.

Actually, most of the water soluble polymers exist as emulsions of discrete particles (500-2000 Å) suspended in water. In most instances it is only necessary to evaporate or dry the solution to achieve the desired results that, in our case, was a continuous but permeable film encapsulating or binding the sorbent granule.

To help narrow the candidate formulations, specific polymeric materials that were known to pose a gaseous barrier were immediately excluded. Similarly, formulations containing plasticizers were also by-passed. In brief, plasticizers are high boilers (glycols, phthalates, etc) that, during the curing process, can migrate to plug pin holes. Small openings in an otherwise continuous film was felt desirable to lessen the CO₂ diffusional barrier.

Each general class of material presented a certain study in itself. Since the original preparation was water-soluble, a water-like nonaqueous solvent was required. In addition, the polymer suspensions resembled large protein molecules in their sensitivity to dissolved salts. Solutions of high ionic strength generally led to a collapse of the suspension resulting in a solution, which resembled curdled milk.

The first member of water soluble polymers to be examined was Carpabol (L. F. Goodrich Chemical Company). At the time of the screening, only the formulation containing the acid ingredients (934, 910) were available. To be effective these preparations required neutralization with long chain amines, which in turn required custom fitting to the solvent (methanol). The results obtained with Carpabol were unreliable, due mostly to the tendency of the viscous or gel-like mixture to collapse in the presence of LiOH.

Polyvinylpyrrolidones

A single sample of PVP was examined next. This material was a member of a series supplied by General Aniline and Film and was identified as K-30. The preparation consisted of a polymer molecular weight of about 40,000. The PVP series are used as binders, stabilizers, etc and form hard transparent films. The manufacturer reports members of this series exert a certain detoxifying effect on some poisons and irritants. Samples were prepared by dissolving the PVP in 100 cc of methanol and mixing 40 cc of solution with 40 g of LiOH. The treated material was dried at 80 C (176 F) overnight. Under these conditions total PVP added to the LiOH was absorbed. The data is presented in table III. The results obtained show significant scatter attributed to nonuniform coating. Scatter is especially evident in the CO₂ data. Significantly, the 1.8% loading effected almost complete repression of dust, although loss of CO₂ activity was extensive.

TABLE III - RELATIVE CO₂ SORPTION CAPACITY AND
DUST INDEX OF PVP TREATED LIOH

<u>% PVP Add-On</u>	<u>Relative CO₂ Capacity (Untreated/treated) (100)</u>	<u>Dust Index</u>
Untreated	100	1.0
0.3	67	0.50
0.5	67	0.56
0.8	93	0.47
1.3	98	0.56
1.5	67	0.28
1.8	20	0.02

We hoped, at this stage, that if a film coating could preserve granule structure, subsequent techniques could then be employed that could render the same film permeable to CO_2 and water. There followed several attempts to pretreat LiOH granules with naphthalene before applying the PVP overcoat. By use of subsequent high temperature and vacuum, naphthalene was expected to sublime from within and below the PVP coat, rendering the PVP film more porous. The results were erratic and the effort was quickly terminated.

Acrylic Latex Emulsions

Interest in polymeric systems now focused on acrylic latex emulsions in which more reproducible and consistent results were achieved. Shown in table IV are the results obtained using the Hycar, Geon and Rhoplex series. Results obtained using a Gantrez sample and a latex emulsion (WC-130) of uncertain composition are also included.

These samples were prepared by diluting 2.5 g of the as-received preparation with 20 cc of water and eventually diluting this solution to 500 cc with methanol. The lithium hydroxide was then dipped into the solution of the polymer for a period of 10-15 seconds, or until all granules were obviously wetted. There followed a 10 second run-off of excess solution, followed by drying at 80 C (176 F) under vacuum for a period of 15 hours. These conditions were selected as they represented conditions that could be compatible with all of the preparations. Not all preparations behave similarly. Some, for example, curdled (emulsion breaking) in the presence of the dissolved alkali. This was especially prevalent when the polymer was maintained in contact with the dissolved LiOH , as in stored run-off solution. The significance of this is that dipping on a large scale basis is not recommended. Dipping in this instance was merely a convenience.

The significance of the data presented in table IV is that a relatively large number of preparations were found to be effective dedusters. A few items showed increased CO_2 activity. Hycar 2518 showed excellent depression of dust formation and also measureable improvement in CO_2 removal capacity over the untreated lithium hydroxide. Gantrez 8194, on the other hand, gave maximum increase in CO_2 activity, but showed little or no tendency to diminish dusting. Maximum depression of dust was obtained with Hycar sample 1571. This material reduced the dust to only 6% of the untreated value and yet maintained the original activity toward CO_2 . The results of the initial screening program clearly indicated the potential for organic polymeric systems, even though these results were obtained without attempt to optimize each preparation. A preliminary effort was then initiated to select the leading candidate material.

TABLE IV - CO₂ SORPTION AND DUST INDEX OF
LATEX TREATED LICH

<u>Polymer Type</u>	<u>Relative % CO₂ Activity (Treated/Untreated) (100)</u>	<u>Dust Index (Treated/Untreated)</u>
Hycar 1561	100	0.12
1571	100	0.06
1572	99	0.11
2518	109	0.09
2570 x 1	105	0.11
2570 x 5	104	0.09
2600 x 94	99	0.75
2600 x 112	99	0.71
2601	99	0.22
2671 ¹	110	0.71
2600 x 148	90	0.43
Geon 576	99	0.11
450 x 3	99	0.11
Gantrez ² AN-8194	110	0.95
Rhoplex L-32	97	0.09
B-15	95	0.68
AC-55	95	0.85
ASE-60	95	0.90
WC-130 ¹	95	0.38

(1) Dissolved in 500 ml MeOH.

(2) Dissolved in 500 ml Petroleum Ether.

Gantrez AN-8194

Although the Gantrez sample showed good CO₂ activity, its results as a deduster were somewhat discouraging. An additional series of runs were made with this sample over an extended range of loadings. The intent was that since Gantrez 8194 showed no loss in CO₂ activity it would be possible to use higher loadings in an attempt to decrease dusting. The Gantrez concentration in the 500-ml methanol bath solution was increased from 0.5 to 1.8% in small increments. The results obtained are given in table V.

The data clearly indicates that although improvement in CO₂ capacity is possible at lower add-ons, Gantrez 8194 is not an effective deduster. We must also point out that whatever advantage the Gantrez-treated material has as a CO₂ scrubber is achieved late in the CO₂ performance curve (i.e., in the vicinity of 0.45 to 0.50% CO₂ breakthrough, the end of the useful life of the bed). The absorption curve generally flattens out in this region and much of the additional CO₂ removal occurs during this time interval.

Rhoplex

Little additional work was done with the Rhoplex series. Although a sample (E-32) of this material showed good performance, it is only a singular sample in a family of compounds that were not good performers. As a result, emphasis shifted to the Hycar series of latexes where much more variety existed.

Geon

Similar to above - no additional screening tests were performed.

WO-130

Same as above.

As is indicated in table IV, the most effective dedusters were in the 1500 and 2500 series of the hycars. These types are characterized by a medium to high content of acrylonitrile. Hycar 1571 is a carboxy-modified butadiene-acrylonitrile. The specific preparations also contain an anionic emulsifier and an antioxidant in a water suspension of 41% total solids. The pH of the original solution is 8.0 and the average particle size is listed as 1200 angstroms. The 2600 series, which were less effective, are modified polyacrylics and generally yield harder film coats. Sample 2600 x 112 is very hard and in conventional uses the stiffness approaches thermosetting plastics.

TABLE V - CO₂ SORPTION AND DUSTING INDEX OF
GANTREZ TREATED LIOH

<u>Gantrez 8194</u>	<u>Relative % CO₂ Capacity (Treated/Untreated)</u>	<u>Dust Index</u>
0.5	110.0	1.0
1.0	80.0	1.0
1.2	89.0	1.0
1.4	86.0	1.1
1.6	89.0	1.2
1.8	83.5	1.2

Additional Hycar Studies

Among the Hycars, 2671 showed maximum CO₂ activity (actually 110% of the untreated material). An effort was made to see if dedusting performance would improve with higher additions. Bath concentrations were examined over the range 0.6% to 0.9% and the data obtained using LiOH as the substrate is shown in table VI. Although the evidence is not conclusive, 2671 appeared to be inferior to 1571 as a deduster.

TABLE VI - DUSTING INDEX VRS. BATH CONCENTRATION
OF HYCAR 2671

<u>% Hycar 2671</u> <u>Bath Conc.</u>	<u>Dust Index</u>
0.6	0.5
0.7	0.33
0.8	0.17
0.9	0.33

Several samples of the 2500 series of Hycar showed better than 100% CO₂ activity. In a head-to-head type screening test 2518 was compared directly with 1571 at several concentrations. Results clearly indicated the superior performance of 1571. At bath concentration of 0.9%, 2518 showed dedusting capabilities rivaling that of 1571, but such results came at the expense of CO₂ activity. For all practical purposes sample 1571 was selected as a special candidate material and additional testing was initiated.

Performance Versus Concentration of Hycar 1571

Table VII shows results obtained when the Hycar concentration in the bath was increased from 0.5% to 1.6%. Results in general show that with bath concentrations less than 5 g/500 cc of methanol the CO₂ performance curve generally lies close to untreated material. As can be observed from figure 3, the general shapes of the curves are quite similar. Preliminary indications are that the most effective bath concentrations are about 0.7% to 0.9%. Above this concentration some loss in CO₂ activity is noted, as shown in table VII.

TABLE VII - CO₂ CAPACITY AND DUSTING INDEX OF
HYCAR 1571 PREPARATIONS

<u>% 1571 Bath Solution</u>	<u>% Relative CO₂ Activity</u>	<u>Dust Index</u>
Untreated	100	1.0
0.5	108	0.21
0.8	99	0.71
0.8	105	0.14
0.9	100	0.11
1.0	---	0.12
1.2	90	0.097
1.4	---	0.091
1.6	83	0.06

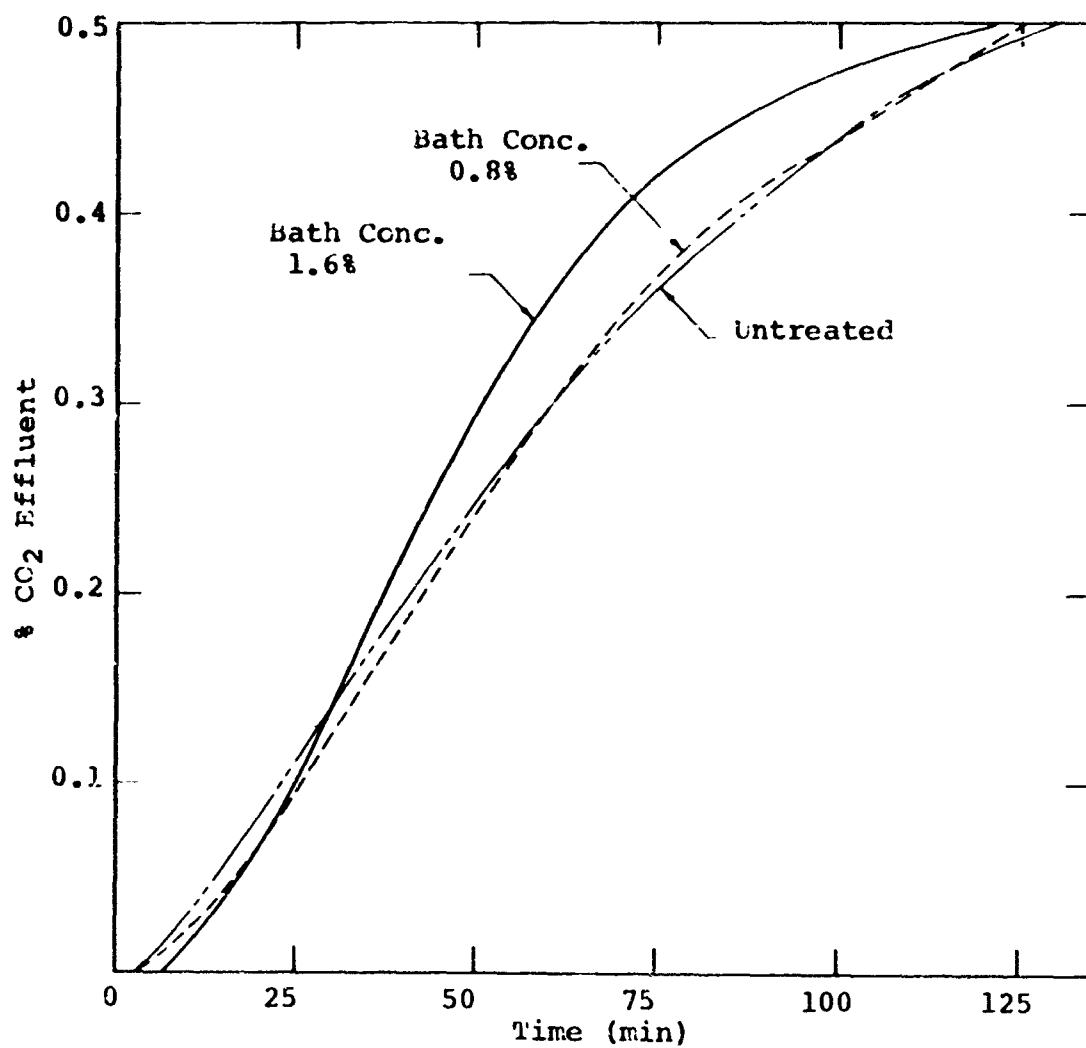


Figure 3. CO₂ Sorption by Hycar Treated LiOH

The data shown in table VII was obtained from a new shipment of LiOH (Lithium Corporation of America) that was 50% less dustier than earlier material. Actually, difference in amount of dust resulted from working the bottom of the old (versus the top of the new) LiOH container.

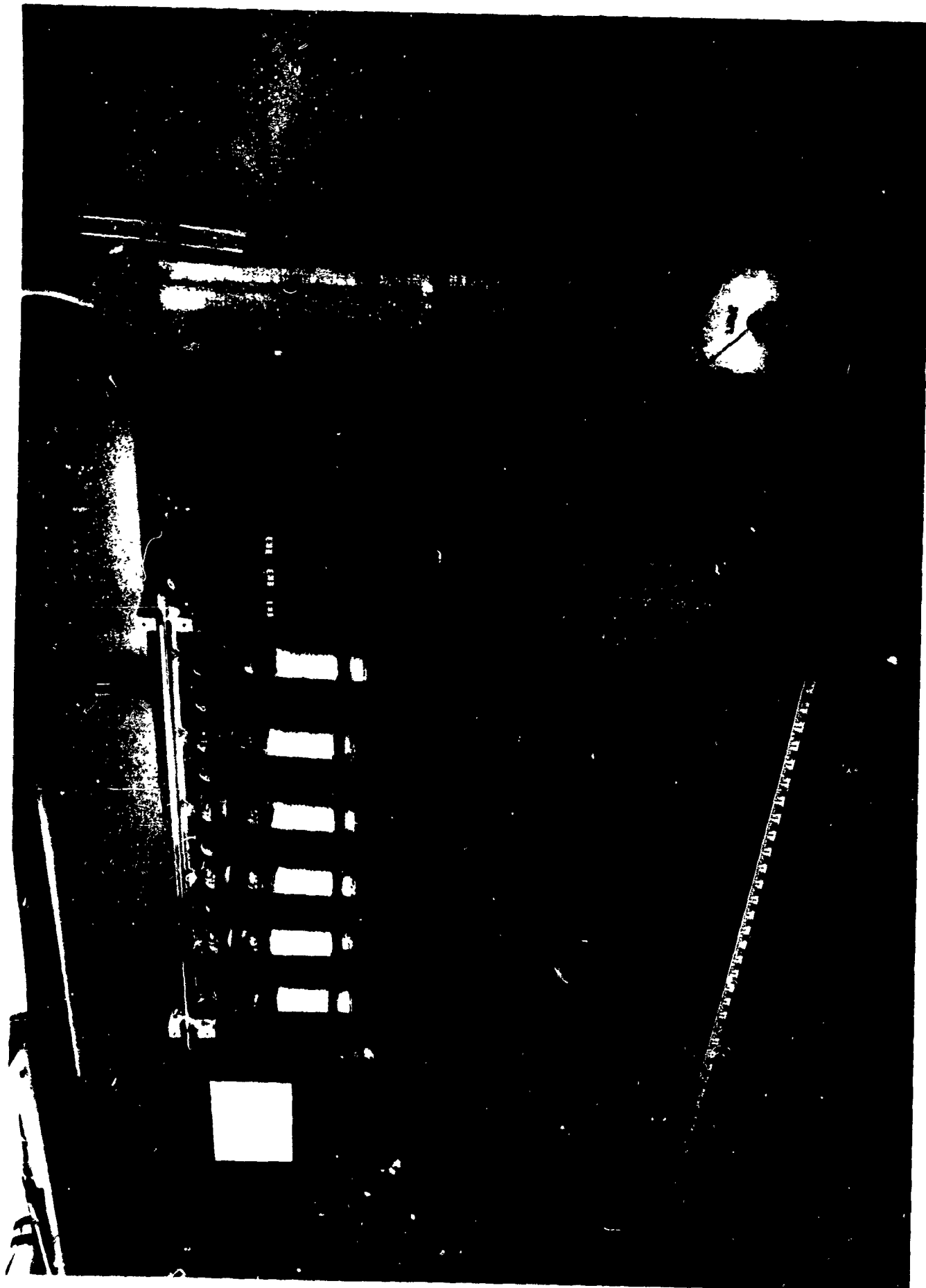
Curing of 1571

Additional reaction in the deposited Hycar film can be induced at elevated temperatures. Many of the Hycar series are temperature sensitive and undergo additional cross-linking at increased temperatures. The manufacturer stated that 1571 may be cured through a reaction with zinc oxide and sodium aluminate. A conventional cure system of sulfur, zinc oxide, and accelerator may also be used to obtain a low elongation, high modulus and high strength product. In general, curing of Hycar 1571 may be effected at room temperature or elevated temperature, depending upon the added ingredients. In the studies that followed, high temperatures alone were used. In general, samples were prepared in the usual manner but dried under vacuum at the indicated temperatures for 2 hours. The results obtained are shown in figure 4 for two different temperatures; 120 C (248 F) and 160 C (320 F). These preliminary results indicated that temperatures of 160 C yield a product with maximum dedusting and minimum loss of CO₂ activity. However, the beneficial effects of high temperature observed in this set of data were not completely substantiated by subsequent tests. In fact, the performance of high temperature cured material is somewhat uncertain. Theoretically, cross-linking the deposited polymer should have resulted in a tighter film that ordinarily should have decreased gas permeability and improved dedusting. The reverse effect, that is, increased CO₂ activity with increased temperature undoubtedly is achieved by the increased permeability, resulting possibly from thermal degradation of the film. The effect of curing at high temperatures is therefore somewhat uncertain. In any event, treated material can be exposed to 170 C (338 F) for 12 hours with no serious adverse effects, although some discoloration occurs. Use of high temperature was most appealing since such treatment would remove trace solvent residuals prior to use of the chemical.

Hycar Blends

From a practical point of view the physical properties of the film coat remained largely unknown. It was therefore of interest to compare an exceptionally hard coat with its opposite (an exceptionally soft coat) and mixtures between these extremes. For this reason synthetic blends of "hard" 2600 x 112 were mixed with soft 1571. A total of 4.0 g of the combined Hycars was diluted to 500 cc with methanol. The blends and compositions are shown in table VIII. The lithium hydroxide was treated by the dip method and, in this case, treated material





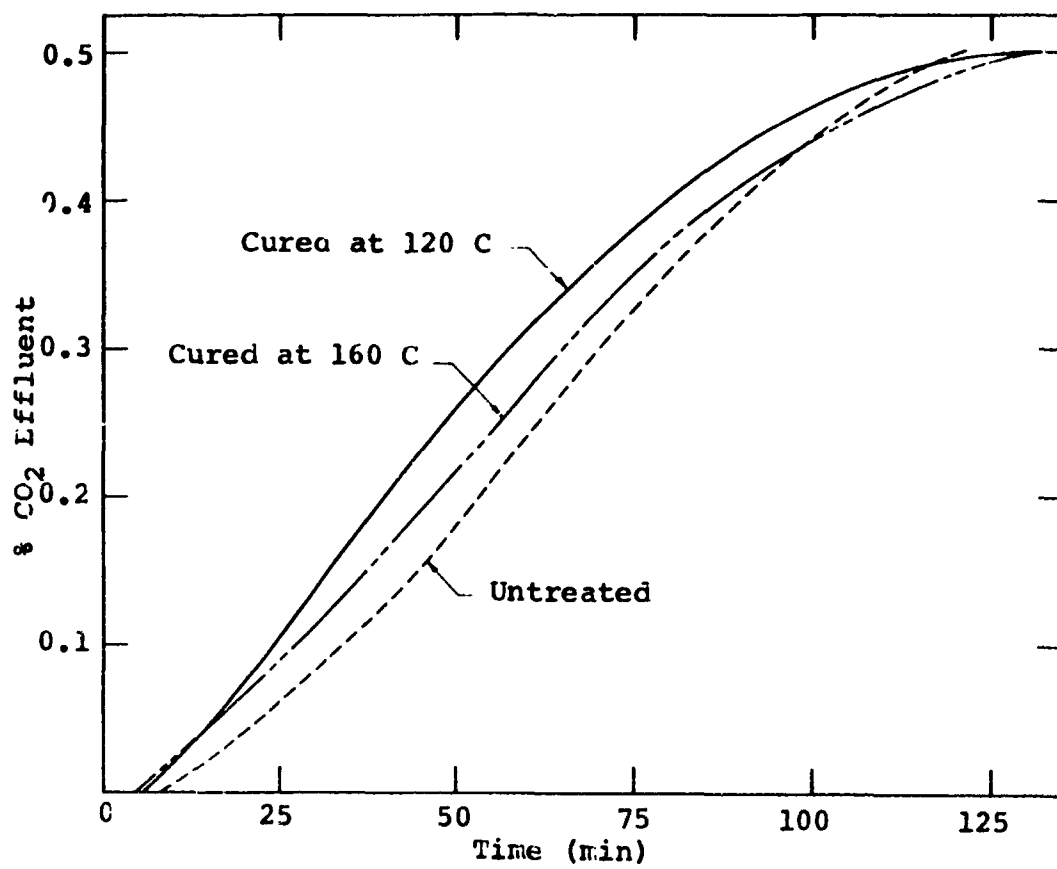


Figure 4. CO₂ Sorption at 25.6 C 80% RH of heat Cured Hycar Treated LiOH

TABLE VIII - PERFORMANCE OF HYCAR BLENDS

% Composition		% Relative CO ₂ Activity (Untreated/Treated)	Dust Index
2600 x 112	2571		
100.0	0	97	0.18
87.5	12.5	97	0.21
62.5	37.5	97	0.14
37.5	62.5	96	0.12
12.5	87.5	95	0.09
0	100.0	96	0.14

was dried at 160 C (320 F) under vacuum for 1.5 hours. Under these conditions (increased drying temperatures) Hycar 2600 x 112 improved considerably and in fact rivaled the performance of 1571. This data indicates a number of polymers that could have been applicable if effort were to be directed towards optimizing each set of conditions.

INORGANIC COATINGS

Inorganic coatings, because of their negligible volatility, were of special interest. In terms of film coating, the number of likely candidates would be extremely limited, since gas permeability is favored by an amorphous or plastic like structure and not by rigid crystalline types characteristic of the inorganic.

Selected starting point were salts that were extremely hygroscopic and major emphasis was limited to the halides of lithium. The method of treatment was again by dipping. This method was selected to achieve a more controllable and uniform amount of loading, especially in the low level region

The literature shows previous use of inorganic salts, especially in the early formulations using lime. In most of these instances, the additive was incorporated into the sorbent during formulation. For our purposes, a surface treatment applicable to a finished item was required.

LiCl and LiBr Treated LiOH

The results obtained by impregnating LiOH (Lithium Corporation of America) with methanol solutions of LiCl and LiBr are shown in tables IX and X. The total lithium salt adhering to the LiOH substrate following the bath treatment was determined by a Volhard Titration, after neutralizing the LiOH with dilute HNO_3 .

The data in general shows the halide treatment to offer improved dynamic CO_2 sorption over an extended range of loadings. Dedusting capability is considerably less than candidate material selected from the organic polymers study.

The significant increase in CO_2 sorption data reported for LiCl loadings of 0.55, 0.92, and 1.67% may have been the results of a poor (poisoned) control run on that particular day. In all cases, increasing quantities of the lithium salts produce significant changes in the CO_2 sorption curve. The CO_2 removal curves for LiOH containing 0.08 and 0.95% LiBr are shown in figure 5. With the higher salt loading, there occurs a certain inhibition period occurring at the start of the run, when a high CO_2 concentration occurs. The severity of this effect is lessened considerably at lower loadings. We suspected, but were never able to verify, that pretreating the prepared bed by exposure to moist air would diminish this inhibitory effect.

LiCl Treatment Effects at Low Relative Humidity

The effect of LiCl treatment on dynamic CO_2 sorption at low relative humidity was of interest to examine. For this study, the LiCl-methanol bath concentration was about 1% in LiCl (5 g LiCl/500 MeOH). Treated LiOH was dried for 3 hours at 140 C (284 F) under vacuum. Bed charge was 10 g and 20 g with the RH reduced to 25-30%. All other conditions remained unchanged. The results are shown in figure 6 and demonstrate the enhanced effect of the LiCl treatment on bed life. As can be observed, the initial high CO_2 breakthrough has occurred in both sized beds. In the 10-g bed (near critical bed depth), the effect is extreme. In the 20-g bed, recovery has essentially taken place within 5 minutes. Additional studies at low RH consisted of varying the bath concentration up to 80 g LiCl per 500 ml of methanol solution. Best results occur where the bath concentration was 10 g LiCl/500 cc MeOH. Normally, this bath concentration yields a LiCl loading of about 1.2 to 1.4% of the weight of LiOH.

Other Inorganic Coatings

Much of the above performance was attributed solely to the hygroscopicity of the LiCl/LiBr. In this case, other similar salts might also qualify. Although a wider spectrum of inorganic salts was not examined, some runs were made using MgCl_2 impregnated LiOH. In all cases, the MgCl_2 treatment seriously inhibited CO_2 sorption.

TABLE IX - PERFORMANCE OF LiCl TREATED LiOH

<u>% LiCl Add-On</u>	<u>Relative % CO₂ Capacity</u>	<u>Dust Index</u>
0.054	105	0.24
0.069	104	0.37
0.10	99	0.48
0.11	94	0.48
0.55	130	0.47
0.92	120	0.47
1.67	120	0.55

TABLE X - PERFORMANCE OF LiBr TREATED LiOH

<u>% LiBr Add-On</u>	<u>Relative % CO₂ Capacity</u>	<u>Dust Index</u>
0.018	113	0.55
0.020	107	0.50
0.036	110	0.34
0.052	106	0.80
0.080	105	0.20
0.22	105	0.23
0.95	116	0.83
1.07	110	0.42

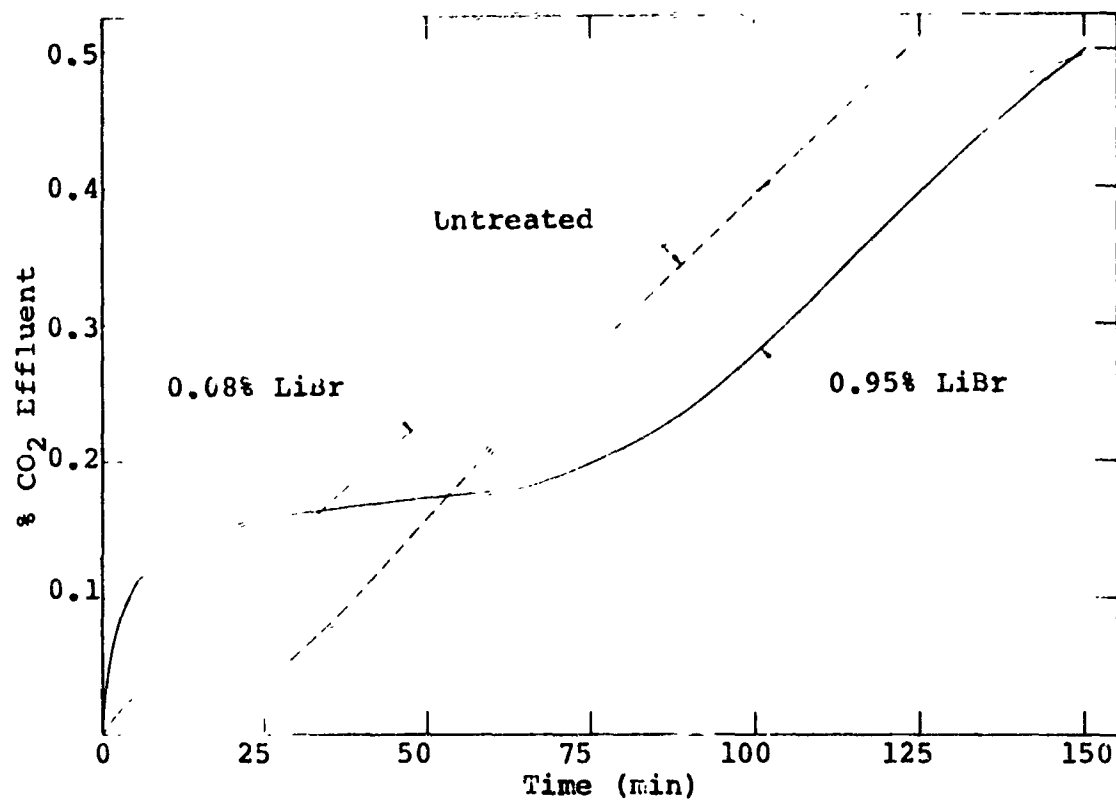


Figure 5. CO₂ Sorption by LiBr Treated LiOH

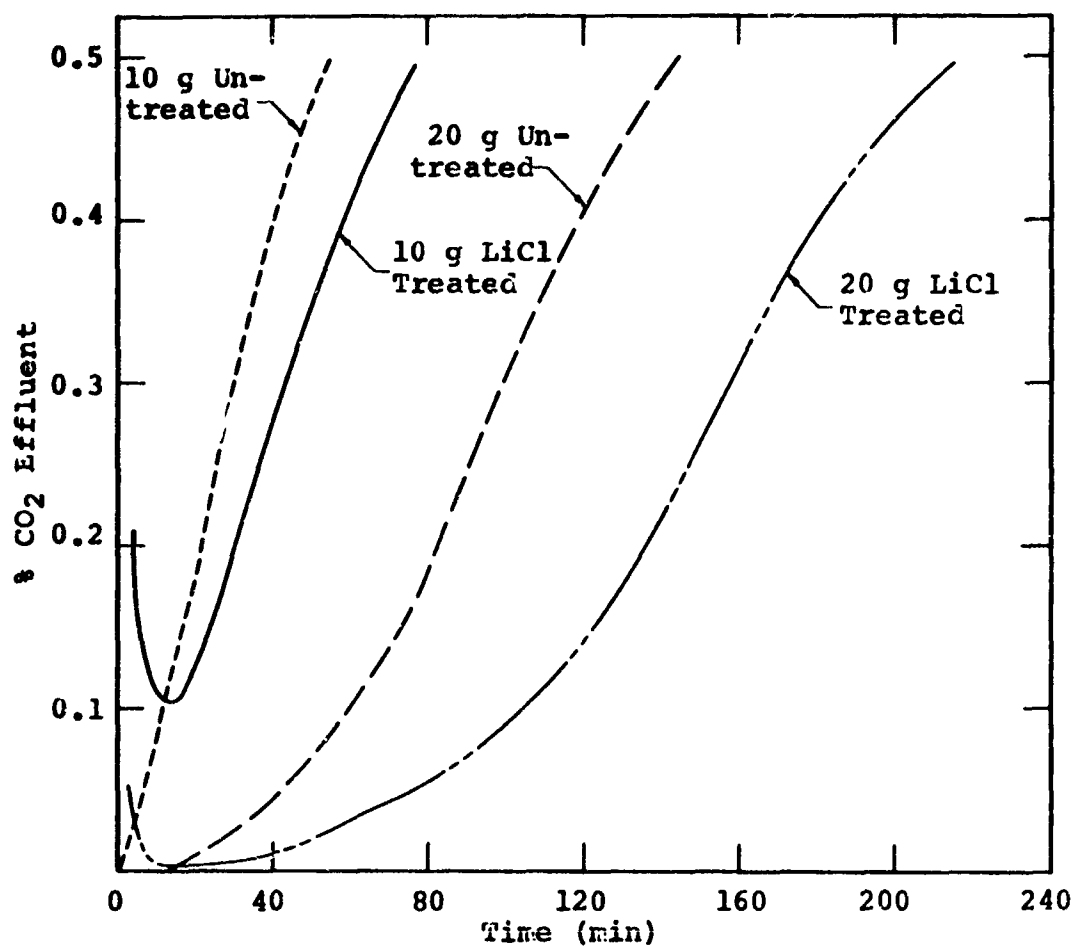


Figure 6. CO₂ Sorption by LiCl Treated LiOH at 23.3 C, 25-30% RH

SECTION IV APPLICATION STUDIES

The previous effort, which was essentially a screening program, evolved two leading candidate systems. The organic polymer, Hycar 1571, showed maximum dedusting capabilities. On a relative basis over 90% reduction of dust was achieved. On the other hand, LiCl-coated LiOH showed considerable promise of improving CO₂ sorption performance, especially in the low humidity region. Additional studies were focused on the application of these candidate materials to other sorbents. In addition, the effectiveness of the treatment was evaluated with LiOH from different sources.

BARALYME

Although emphasis was placed on LiOH as the principal CO₂ sorbent, some attempts were made to examine Hycar 1571 on Baralyme. In general, the results were unsuccessful. The major difficulty was suspected to be the high water content of the Baralyme. To be an effective CO₂ scrubber, Baralyme must retain its water content of about 17%. Hycar, on the other hand, must be dried to achieve proper film forming properties. Results obtained wherein Hycar concentrations in excess of those used earlier for LiOH were applied to Baralyme, demonstrated negligible dedusting. The CO₂ sorption data was scattered but indicated significantly decreased dynamic CO₂ capacity. The results in general showed that special custom fitting of the treatment method to Baralyme would be required. The same difficulty would be expected in applying Hycar to other sorbents, such as sodalime, although Hycar would work best on dry sorbents.

OTHER LiOH SOURCES

At this point the candidate material and treatment method were actually based on a single source of LiOH. It was of interest to apply the same surface treatments to other LiOH preparations. Available for testing was a CO₂ cartridge from Maywood Chemical Works that was sealed in August 1961. The material was further identified as Stock No. PF6810-559-3261 and presumably was packaged for the U. S. Navy.

A five pound container of LiOH environmental grade (Mil-L-202130) was obtained from Foote Mineral Company. This material is more refined and is specifically intended for life support systems (Mil-L-2021BD). The LiOH in this batch is guaranteed to remove at least 0.7 g CO₂/g LiOH. Also compared in the following test was LiOH from Lithium Corporation of America. This latter material also meets the same military specifications, but its cost is considerably less than the LiOH obtained from Foote Mineral Company. The intent of the

following test was to examine the same surface treatment on a number of LiOH types, each of which could presumably offer a different surface characteristic. Samples were treated separately by dipping, following the procedure described below:

1. 100 g samples of LiOH were shaken lightly in a 20-mesh Tyler screen to remove dust already present.
2. The LiOH was spread out in a thin layer on a 17.6 cm x 29.2 cm flat tray of stainless steel screen. Hycar 1571 bath solution was prepared in advance and consisted of diluting this suspension with 20 ml of water and further diluting to 1000 ml with methanol. A LiCl solution was prepared by dissolving the LiCl in methanol (cp).
3. The tray containing the granules was immersed in 1000 cc of bath solution in a porcelain tray.
4. Immersion time was limited to 15 seconds. Each tray was drained for about 20 seconds.
5. Treated material was spread out on porcelain dishes and dried under vacuum.

Prior to this time, testing was performed on 15-g beds. For this test, bed charge was increased to 40 g. Increasing the bed charge gave a new bed height of 10 cm to 11.5 cm. This height is more realistic in canister use situations. Hycar-treated LiOH was run at 80% RH, whereas LiCl treated LiOH was examined at 15-20% RH. All other test conditions remained unchanged.

Six 10-g beds were run at one time and to maintain a flow of 4000 cc/min through each bed the line pressure was 5-6 cm of mercury. Dusting was evaluated using the tumbling method. Carbon dioxide performance curves for Hycar treated LiOH are shown in figures 7 and 8. Similar curves for LiOH from Lithium Corporation of America are not presented since treated and untreated were congruent. Figures 9, 10, and 11 present the effects of LiCl treatment on dynamic sorption under dry conditions. Results are tabulated in tables XI and XII.

In general the results show that the Hycar treatment exerts a significant dedusting influence on all sorbent granules. In the samples from Lithium Corporation of America and Foote Mineral Company no overall adverse effects on CO₂ capacity were

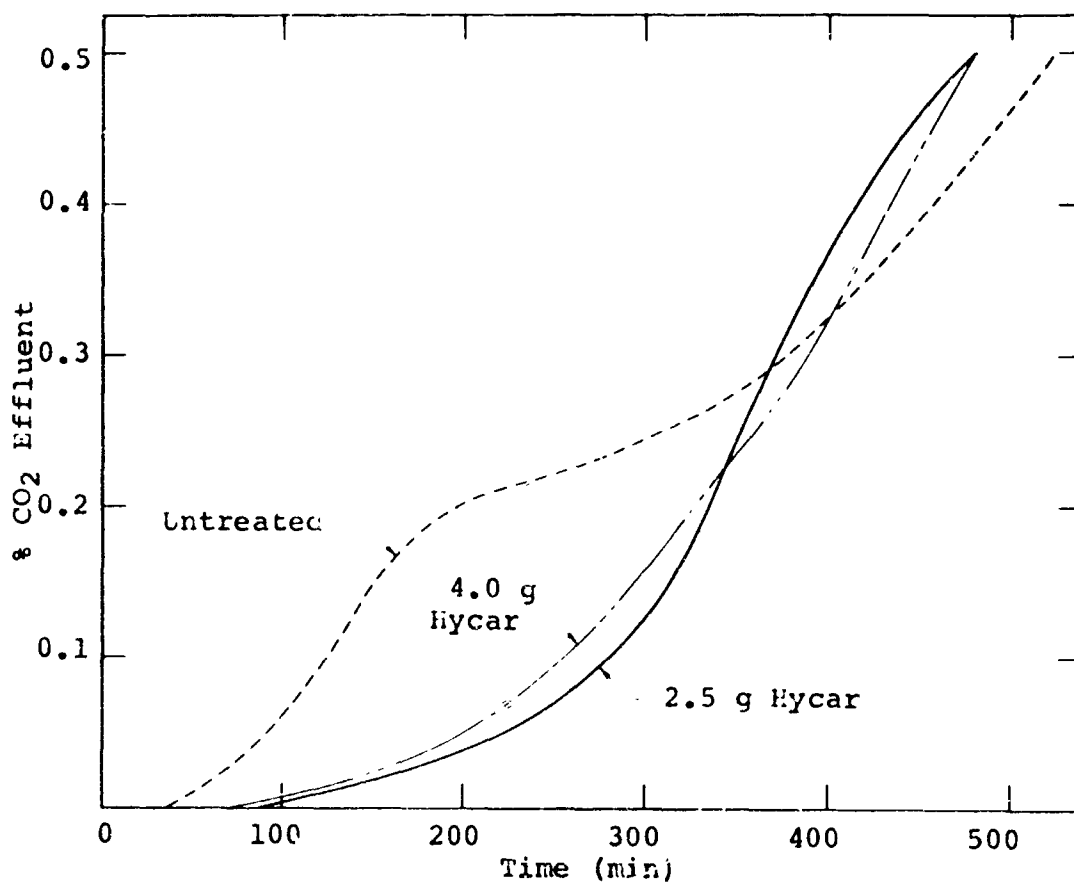


Figure 7. CO₂ Sorption at 22.8 C 80% RH of
Hycar Treated LiOH
LiOH From Foote Mineral

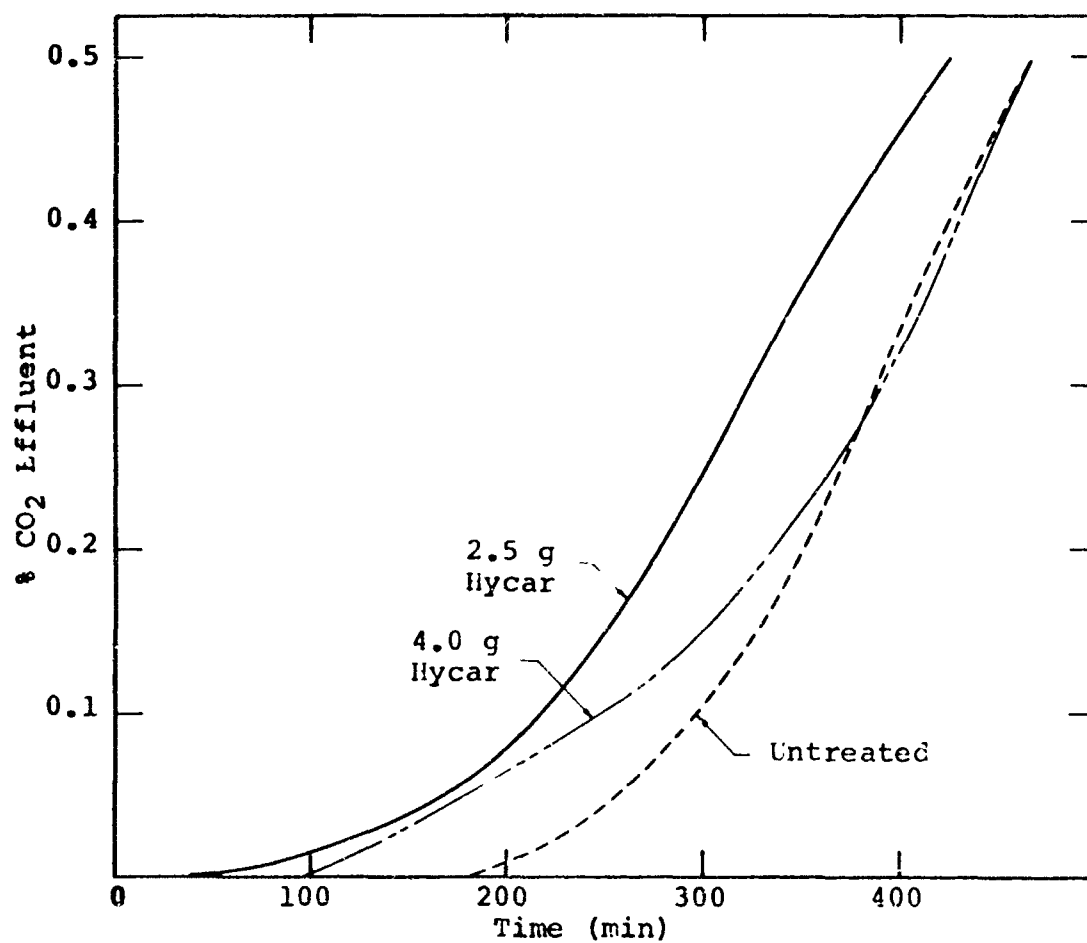


Figure 8. CO₂ Sorption at 22.8 C 80% RH of
Hycar Treated LiOH
LiOH From Maywood Chemical Works

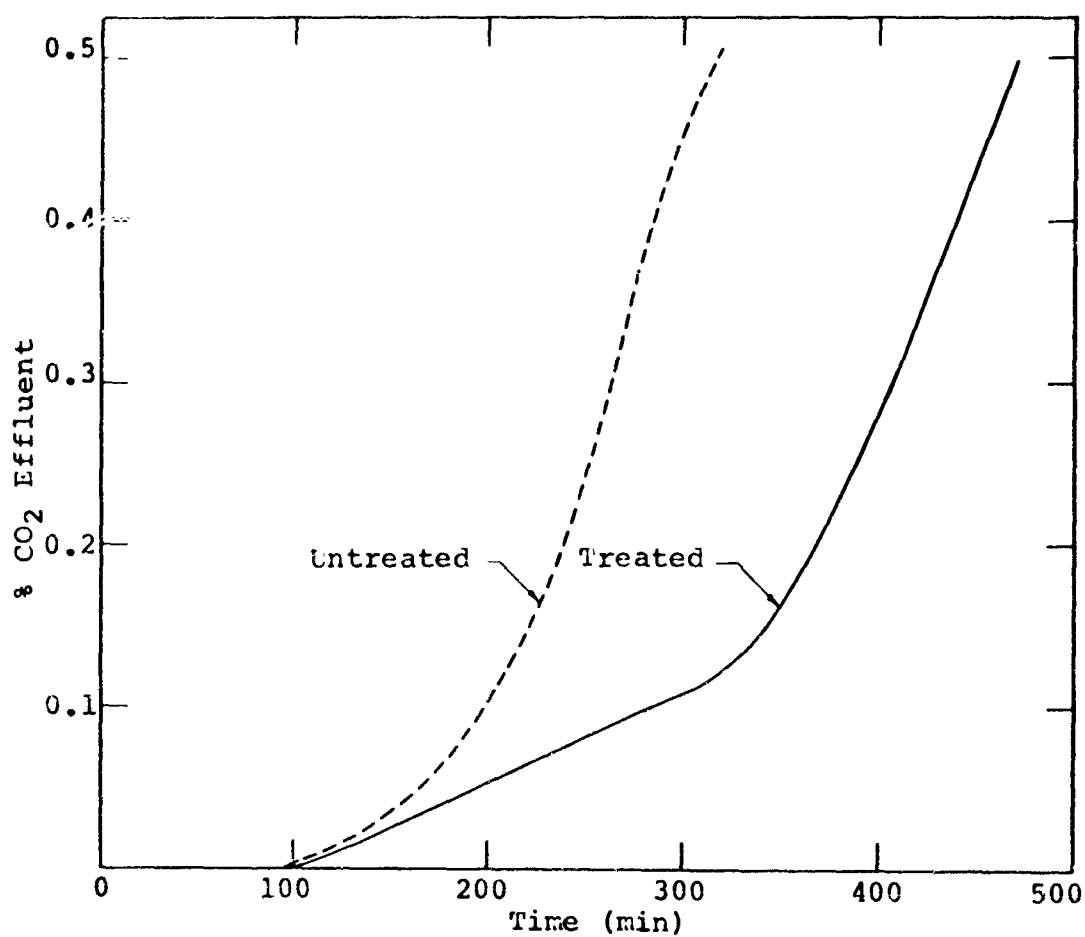


Figure 9. CO₂ Sorption by LiCl Treated LiOH at
22.8 C 15-20% RH

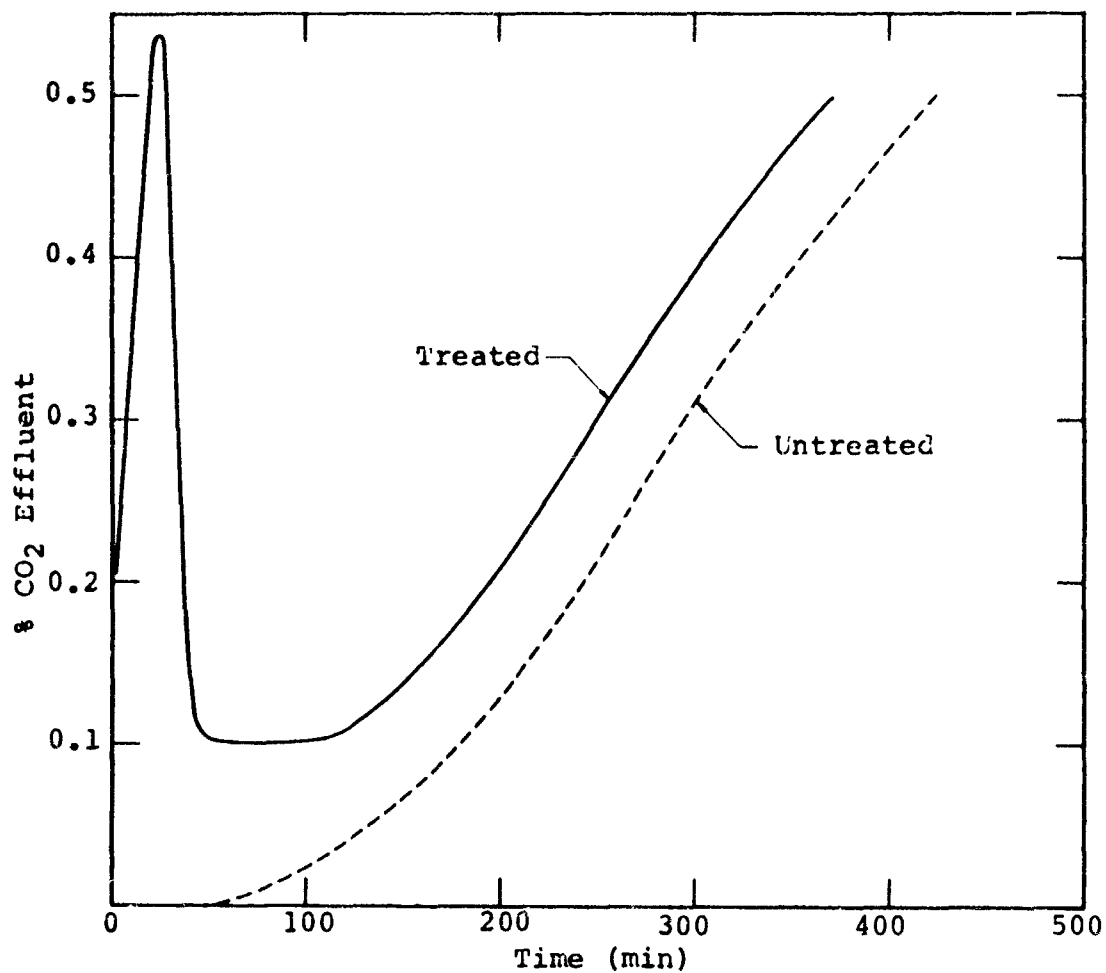


Figure 10. CO₂ Sorption at 22.8 C 15-20% RH cf
LiCl Treated LiOH
LiOH From Foote Mineral Co.

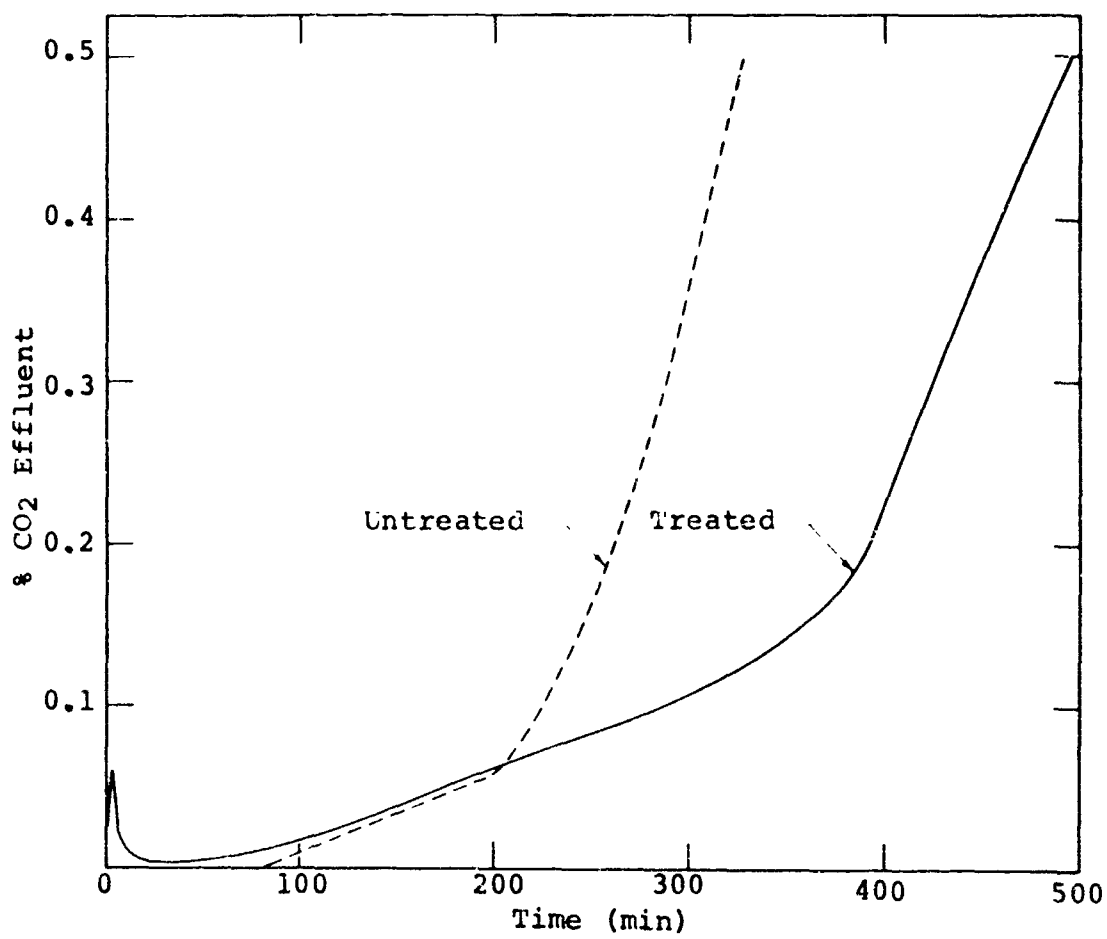


Figure 11. CO₂ Sorption at 22.8 C 15-20% RH of
LiCl Treated LiOH
LiOH From Lithium Corporation of America

TABLE XI - CO₂ SORPTION AND DUSTING DATA OF HYCAR 1571
TREATED LiOH. CO₂ SORPTION AT 22.8 C (73 F) 80% RH

LiOH Source	Treatment		CO ₂ Dynamic Capacity g CO ₂ /g LiOH	Dust Factor mg Dust/g LiOH	Dust Index
	Bath Composition	Cure Conditions			
Lithium Corp. of America MIL-L-20213-D	Untreated	None	0.77	2.3	1.0
Lithium Corp. of America MIL-L-20213-D	Hycar, 2.5 g H ₂ O 10 ml MeOH 490 ml	90 C for 12 hrs under 1 mm Hg	0.77	1.1	0.55
Maywood Chem. Works Stock #PL 6810- 559-3261	Untreated	None	0.8	4.8	1.0
Maywood Chem. Works Stock #PL 6810- 559-3261	Hycar 2.5 g 10 ml H ₂ O MeOH 490 ml	90 C for 12 hrs under 1 mm Hg	0.69	0.66	0.14
Maywood Chem. Works Stock #PL 6810- 559-3261	Hycar 3.5 g 10 ml H ₂ O MeOH 490 ml	160 C for 2 hrs under 1 mm Hg	---	2.3	0.48
Maywood Chem. Works Stock #PL 6810- 559-3261	Hycar 4.0 g 10 ml H ₂ O MeOH 490 ml	160 C for 12 hrs under 1 mm Hg	0.79	1.1	0.23
Foots Mineral Company Environmental Grade Lot #612-7C-3	Untreated	None	0.80	0.7	1.0
Foots Mineral Company Environmental Grade Lot #612-7C-3	Hycar 2.5 g 10 ml H ₂ O MeOH 490 ml	90 C for 12 hrs under 1 mm Hg	0.80	0.24	0.34
Foots Mineral Company Environmental Grade Lot #612-7C-3	Hycar 3.0 g 10 ml H ₂ O	160 C for 2 hrs under 1 mm Hg	0.80	0.17	0.24
Foots Mineral Company Environmental Grade Lot #612-7C-3	Hycar 4.0 g 10 ml H ₂ O MeOH 490 ml	160 C for 12 hrs under 1 mm Hg	0.80	0.31	0.44

TABLE XII - CO₂ SORPTION AND DUSTING PERFORMANCE OF LiCl TREATED LiOH
CO₂ SORPTION AT 22.8 C (73 F) 15-20% RH

LiOH Source	Treatment Method	CO ₂ Dynamic Capacity g CO ₂ /g Sorbent	Dust Factor mg Dust/g Sorbent	Dust Index
Lithium Corp. of America	Untreated	0.68	2.3	1.0
Lithium Corp. of America	10 g LiCl/500 ml MeOH dried at 160°C for 12 hrs under 1 mm Hg	0.84	1.2	0.52
Maywood Chem. Works	Untreated	0.57	4.8	1.0
Maywood Chem. Works	10 g LiCl/500 ml MeOH dried at 160°C for 12 hrs under 1 mm Hg	0.84	1.4	0.29
Footo Mineral Co.	Untreated	0.68	0.70	1.0
Footo Mineral Co.	10 g LiCl/500 ml MeOH dried at 160°C for 12 hrs	0.55	0.36	0.51

observed. With the sample from Maywood, increased dedusting resulted in decreased capacity for CO₂. The starting Maywood material was extremely dusty, averaging about 7 times the dust associated with LiOH from Foote Mineral.

Data compiled on the LiCl treated LiOH shows a favorable increase in CO₂ activity for samples from Lithium Corporation of America and Maywood Chemical Works. In fact, the treatment produced a superior product for CO₂ sorption in the low humidity region. As is obvious from the sorption curve, the presence of LiCl on the Foote samples decreased CO₂ sorption. However, the curve for the treated material is characteristic of an excessive loading (see figure 10). Flow resistance in the LiCl treated beds both before and after these tests indicated no increase that would have resulted if serious caking had formed. Also indicated by the data is the need to optimize or tailor each preparation to the particular substrate. Thus, samples from Foote Mineral and Lithium Corporation could undoubtedly withstand increasing amounts of Hycar add-on since no observable loss in CO₂ capacity was noted. On the other hand, the Maywood sample showed that even the least amount of Hycar affects CO₂ sorption. Similarly, the LiCl treatment led to improved products with samples from Maywood and Lithium Corporation of America, but the same treatment seriously impaired the activity of the LiOH from Foote Mineral Company.

HIGH VELOCITY FLOW DEDUSTING

The measure of dusting tendency of sorbent particles developed earlier in the program was a somewhat empirical test. A less empirical method for final evaluation of the dust tendency was thought highly desirable.

The tendency to split off dust from the surface of LiOH particles is known to become extensive at a critical velocity of about 2250 cm/min (75 ft/min). Treated and untreated LiOH particles were subjected to bed velocities greater (4620 cm/min [150 ft/min]) and less (1320 cm/min [44 ft/min]) than the critical velocity. The LiOH from three different sources were included in the tests. Lithium oxide was included for comparison at the lower velocity.

A 10-g sample of material was supported on a wire screen. Compressed air, which was filtered through an ultra-fine cellulose membrane, was allowed to flow from the bottom to the top of the bed. Particulate matter released from the test particles was sampled isokinetically and measured by use of a Royco Model 200A Particle Counter. Particles counted were in the size range of 0.5 to 0.64 microns. This is the normal particle size used to monitor contamination levels in "clean" rooms. Tests at both velocities were conducted on static material beds. At the lower velocity an additional test was

run in which vigorous agitation was imparted to the material bed by means of an electric pencil to evaluate dusting at considerably more stringent conditions.

Particle counts obtained over a 1 min period, with air flow of 1320 cm/min (44 ft/min) through static beds, are shown in table XIII.

The effectiveness of the sorbent treatments is clearly shown. The Hycar treatment reduced the number of dust particles by at least a factor of three compared with untreated particles. In the case of LiOH from the Lithium Corporation of America, dust was reduced by a factor of 10. The LiCl treatment increased the amount of dusting when the amount of additive was 0.8 weight percent. When the concentration of LiCl was increased to 1.3%, the dust count was at the lowest level.

The results of the LiCl treated LiOH were very surprising. Previous results in which granules were tumbled did not show such favorable performance for LiCl treated material. A possible explanation for the dedusting performance of the 1.3% LiCl add-on is that it yields dust with a minimum quantity in the 0.5 to 0.6 micron region. Another and perhaps more plausible explanation is that dusting was diminished by moisture, perhaps from the laboratory air used in these tests. Normally, the RH of compressed air in these laboratories is about 25%. Time did not permit the examination of the dedusting performance of LiCl treated LiOH after exposure to various RH values.

In table XIV, particle counts are given for the same flow velocity but with vigorous agitation of the bed. The third column in the table indicates the amount of dust particles adhering to the surface of the sorbent particle. The number of minutes necessary to reduce the particle count to background also indicates that the 0.8% LiCl treatment actually increases the amount of dusting. The agitation did not cause any vertical movement of particles but did cause a horizontal movement in a circular direction. The agitation did have the advantage of producing a dust count that gave the appearance of steady state conditions for a period of 10 minutes. The effect of the Hycar treatment is less effective but still effects a significant decrease in dust. The LiCl treatment did not materially change the amount of dusting. The various sources of the untreated LiOH presented striking differences in dusting tendency. The Maywood product gave even less dust at steady conditions than the Hycar treated Maywood product. The lithium oxide gave approximately the same amount of dust as the Hycar treated material. Particles counted at the 4620 cm/min (150 ft/min) flow velocity are tabulated in table XV. The differences that were apparent at the lower velocity were minimized at the higher velocity. The surface treatment evidently has little effect on the amount of dust split off at these high velocities. We thought that at these velocities there is sufficient movement of the granules to cause mechanical wear.

TABLE XIII - PARTICLE COUNTS OF DUST (0.5-0.64 μ) ELUTED
FROM TEST BEDS AT 0.22 m/sec (44 ft/min) VELOCITY

<u>Material</u>	<u>No. of Particles Initially Counted in One Minute</u>	<u>No. of Minutes to Reduce Count to Background</u>
Hycar treated LiOH (LCA ¹)	112	2
Hycar treated LiOH (Maywood ²)	385	4
LiCl treated LiOH (1.3% LiCl)	16	2
LiCl treated LiOH (0.8% LiCl)	1115	17
LiOH (LCA ¹)	1149	7
LiOH (Maywood ²)	1225	3
Li ₂ O	120	5

¹ LiOH from Lithium Corporation of America
treated with 4 g Hycar/500 ml MeOH.

² LiOH from Maywood Chemical Works
treated with 4 g Hycar/500 ml MeOH.

TABLE XIV - PARTICLE COUNTS FROM AGITATED BEDS
AT 0.22 m/sec (44 ft/min) FLOW

<u>Material</u>	<u>No. of Particles Counted in One Min.</u>		
	<u>Initially</u>	<u>Steady Conditions</u>	<u>Agitation Stopped</u>
Hycar treated LiOH (LCA ¹)	1227	500	0
Hycar treated LiOH (Maywood ²)	291	310	5
LiCl treated LiOH (1.3% LiCl)	1776	1900	9
LiCl treated LiOH (0.8% LiCl)	3358	2500	11
LiOH (LCA ¹)	2251	1900	0
LiOH (Maywood ²)	692	90	10
Li ₂ O	593	250	3

¹ LiOH from Lithium Corporation of America
treated with 4 g Hycar/500 ml MeOH.

² LiOH from Maywood Chemical Works
treated with 4 g Hycar/500 ml MeOH.

TABLE XV - PARTICLE COUNTS AT 0.77 m/sec (150 ft/min) FLOW

<u>Material</u>	<u>No. of Particles Counted in 1 Minute</u>
LiCl treated LiOH (1.3% LiCl)	3502
LiOH (Maywood ²)	2754
LiOH (LCA ¹)	1509
Hycar treated LiOH (LCA ¹)	3491
LiCl treated LiOH (1.3% LiCl)	3502

¹ LiOH from Lithium Corporation of America
treated with 4 g Hycar/500 ml MeOH.

² LiOH from Maywood Chemical Works
treated with 4 g Hycar/500 ml MeOH.

SECTION V CONCLUSIONS

The particles released from LiOH during dusting are approximately 0.5 microns in diameter and require high efficiency filtration for their removal. Since particles of approximately 0.3 microns in diameter are known to be the size most effectively retained in human lungs, the retardation of dust from CO₂ removal sorbents would reduce the engineering complexity of life support/CO₂ removal systems.

The most superior dedusting coating evolved from the screening program was a high acrylonitrile butadiene latex polymer. This material (Hycar 1571, B. F. Goodrich Chemical Company), when added to LiOH, showed excellent dedusting capabilities. By using a single sorbent substrate and optimizing the treatment method, over 90% decrease in dust was achieved with little or no loss in CO₂ capacity. The latex treatment must be tailored for LiOH obtained from different vendors. While most of the studies have been done with LiOH from the Lithium Corporation of America, optimization of this treatment for other sources of LiOH has not been attempted.

Treatment of LiOH with LiCl tends to improve CO₂ capacity but LiCl is less effective as a deduster than the latex polymer. LiCl-treated LiOH shows exceptional promise of extending the use of LiOH into the low humidity region. Data shows bed life of LiCl treated LiOH at 23.9 C (75 F) and 15-20% RH is comparable to the life of untreated material at 23.9 C (75 F), 80% RH. The primary benefit of LiCl treatment is the significant improvement in dynamic CO₂ capacity when the LiOH is used in a low humidity environment. This improvement is apparently a result of the deliquescent nature of the LiCl coating.

Because of the peculiarities of each sorbent surface maximum results can best be achieved by custom fitting the treatment to each surface. This is the case with LiOH from different vendors. This specificity is further demonstrated by the lack of success experienced in treating other CO₂ sorbents (e.g., Baralyme) with LiOH-optimized treatments.

Surfactants can diminish dusting provided sufficient loading is present. In general, the critical magnitude of the surfactant loading is of the order of 1 to 2%. At this level, however, vapors of the surfactant could easily be swept from the sorbent beds presenting a possible toxicological threat. Nonpolymeric or free amines that might improve CO₂ activity also pose a similar threat.

Hycar (latex) treated LiOH appears compatible for CO₂ removal in life support systems where high efficiency dust filtration is not possible. Examples might be in weight or volume limited systems, such as extra vehicular space life support or advanced semiclosed cycle SCUBA gear.

Lithium chloride treatrents are useful for systems where CO₂ removal is done at low humidity. Examples might be in dry life support environments. Such a chemical might also be used for CO₂ removal in air breathing systems, where CO₂ might affect system operation. Examples are air breathing fuel cells and oxygen concentration devices presently being developed for aircraft application.

SECTION VI RECOMMENDATIONS

Following are suggested areas where promise exists for further improving the operational capabilities of non-regenerable CO₂ sorbents:

1. Optimization of water soluble resin and LiCl pretreatments. Examine the role of the solvent, method of application and curing process in detail. With polymers, application by spraying, use of a prewash with solvent alone, and application of a series of thin coats are possible means of optimizing treatments.
2. Examine dusting tendency of LiCl-treated LiOH after exposure to various amounts of moisture. Determine the effects of aging under humid conditions.
3. Evaluate halide treatments more definitively to further enhance dynamic CO₂ sorption under low humidity conditions.
4. Attempt to combine Hycar and LiCl treatments to effect maximum dedusting and improve dynamic CO₂ sorption capability.
5. Determine effectiveness of surface treatment for use in semiclosed or closed cycle single man breathing system (~4% CO₂ in air).
6. Definitive studies on specific treatments for other sorbents such as lithium peroxide.

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13. ABSTRACT

Surfaces of carbon dioxide sorbent granules were treated with various liquid preparations to diminish dusting tendency and to improve carbon dioxide capacity. Emphasis was placed on a screening program whereby granules of lithium hydroxide were impregnated with solutions of surfactants, organic polymers, and lithium halide salts. Relative effectiveness of treatment was evaluated using a carbon dioxide dynamic capacity test and a dust test. Studies show that latex emulsions significantly diminish dusting tendency of lithium hydroxide granules with only negligible loss in carbon dioxide sorption capacity. Lithium chloride-treated lithium hydroxide results in significantly improved carbon dioxide capacity at low humidity, but such treatment is generally less effective as a deduster than the latex preparation. Excess loadings of surfactants were required to diminish dusting to acceptable limits. (

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